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K_A channels reduce dendritic depolarization from synchronized synaptic input: implication for neural processing and epilepsy

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Background

During cognitive tasks, synchrony of neural activity varies and is correlated with performance. There may however be an upper limit to the level of normal synchronicity and e.g., epileptogenic activity is characterized by excess spiking at high synchronicity. Furthermore with regard to neuronal excitability, synchronous input is the most effective input. In epilepsy an A-type potassium channel (K_A) has been implicated. More specifically, a mutation in a K_A gene was found in a temporal lobe epilepsy patient [1] and a highly selective blocker of K_A induced seizures [2]. An objective of this work was to investigate if $K_A$could suppress synchronized synaptic input while minimally suppressing semi-synchronous input.

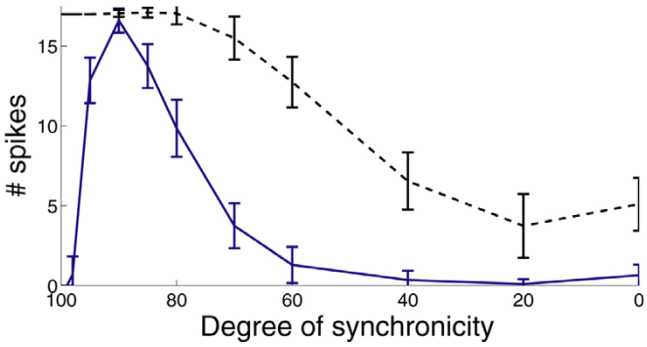

Figure 1
Synchronized input is strongly suppressed by K_A. The figure shows the number of spikes produced for different synchronicity levels. The dashed line represents baseline (control without K_A) and the continuous line with K_A. Note the pronounced suppression in the interval 100-90%.

Methods

We used a cell model of a hippocampal CA1 pyramidal neuron based on Migliore et al [3]. It is composed of 566

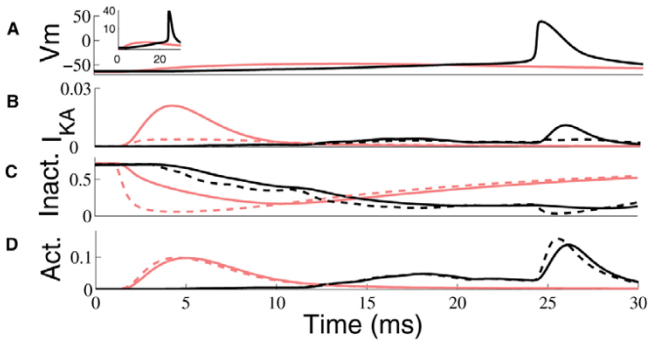

Figure 2
K_A selectivity originates from its fast activation and slow inactivation. Activation of K_A by synchronized versus semi-synchronized input. The continuous black lines represent synchronous input (100%), the gray lines semi-synchronous input (70%). The dashed lines represent values of K_A steady-state activation and inactivation at the membrane potentials dictated in A. **A**: Membrane potential in the soma. **B**: Current through K_A at input site. Note the difference in current around 4 ms. **C**: Inactivation of K_A at input site. The interval 2–10 ms shows that the effect seen in B originates from the dynamical aspects of K_A. **D**: Activation of $K_A$at input site. Note activation around time of input 2–10 ms.

compartments with Na, K_{dr} and K_A -type currents of Hodgkin-Huxley type. Ten synaptic inputs were added on a medial compartment. The simulation was run for 1.5 s and repeated 15 times with different levels of synchronicity. To estimate the standard deviation, the procedure was repeated 20 times with different random seeds.

Results

See Figures 1 and 2

Discussion

Our model shows that K_A differentially suppresses responses to varying levels of input synchrony. The study indicates that the selectivity of K_A originates from its dynamic interaction between fast activation and slower inactivation in response to the waveform of a synchronized input, in the voltage region: -60 to -30 mV.

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